INDICES FOR ASSESSING LANDSCAPE LEAKINESS AT MULTIPLE SCALES

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INTRODUCTION

It is generally accepted that healthy rangeland landscapes are those that function to conserve resources by retaining water, soil and nutrients. How well landscapes retain, not 'leak', water and soils is largely determined by the cover and spatial arrangement of perennial (more permanent) patches of vegetation. We have developed a leakiness index based on very high resolution remote sensing that indicates degree of resource retention on hillslopes (Ludwig *et al.*, 2002) and thereby provides an index of landscape function. This index should allow up-scaling of ground-based landscape function assessment that is now an established procedure in some agency monitoring programs. However, there is a need to continue this up-scaling process so that indicators of potential leakiness are available for application at larger landscape scales. In this poster paper we briefly review features of current leakiness indices and point to planned further developments.

DIRECTIONAL LEAKINESS INDEX (DLI)

This index is applied at hillslope scale by sampling areas up to several hectares. Images of very high pixel resolution (e.g. 0.2 – 2.5 m pixel size) are used. Smaller pixel sizes (and image size) are typically available with aerial videography. Satellites such as Quickbird and Ikonos now supply multispectral imagery of ~2.5 m pixel size for areas of >100 sq km. Pixels need to be classified into either patch or fetch: patches are resource-conserving clumps of perennial vegetation (typically trees, shrubs and tussock grasses) while fetches comprise bare ground, and areas covered by litter and annuals. DLI assumes directional flows down the hillslope and the image area of interest is rotated so that flow is down columns of pixels. On relatively flat areas where flow direction may be uncertain, we calculate leakiness down columns and across rows, then average the two values to obtain a multi-directional leakiness index. DLI is scale dependent and scaling criteria are applied to standardise index values obtained from hillslopes of different size.

The index has been published; index formulation and a demonstration of its application are available in Ludwig *et al.* (2002). DLI has been compared against other potential indicators of landscape leakiness and produced similar results to the lacunarity index (Bastin *et al.*, 2002). While lacunarity is based on the size of gaps (= fetches) in the image, it does not appear to account for the locations of gaps as well as does DLI. Testing showed that DLI better indicated leakiness in images, compared with lacunarity, as patch cover decreased. The DLI program is available from Adam Liedloff (in Visual Basic) or Vanessa Chewings (Fortran version).

COVER-BASED DLI (CDLI)

This index overcomes the limitations of the binary patch-fetch classification of DLI, particularly when working with the larger pixel sizes that are commonly available from satellite imagery. It uses continuous cover within pixels. Cover is estimated with an appropriate vegetation index such as the PD54 index for the predominantly red soils of central Australia (Pickup *et al.*, 1993). This index:

- Is recommended for hillslopes (or portions thereof) up to about 1200 m in length. The method is scale dependent so we recommend image sample-size criteria for its use.
- Is suitable for the larger pixels of high resolution satellite imagery (e.g. 15 m Landsat TM panchromatic, 30 m Landsat TM multispectral, 10 m SPOT XS, 20 m SPOT MSS). A cautionary note here is that the higher resolution panchromatic band may not reliably indicate cover.

- Calculates a progressive leakiness value down the hillslope based on the assumption that areas (pixels) with higher cover tend to retain more resources while pixels with lower cover leak resources.
- Requires that the image area (hillslope) is rotated so that resource flows are down columns. We suggest that features such as hills and the drainage network should provide suitable context to determine the required image rotation.

A paper describing the method and its application is currently under peer review before being submitted to a journal (probably *Ecological Indicators*).

LEAKINESS & HIGH RESOLUTION DIGITAL ELEVATION MODEL

A leakiness index that includes information about flow direction from a DEM is currently under development. We envisage that the index will be a refinement of CDLI that estimates the potential leakiness of each pixel with progressive leakiness accumulating in the DEM flow direction rather than directly down columns. Likely features include:

- The ability to rapidly estimate potential leakiness where a high resolution DEM exists. There are few examples of this to date in the rangelands but this is changing with new sources of remotely sensed data (e.g. ASTER satellite imagery).
- Increased index precision compared with DLI and CDLI through the ability to consider non-linear flow directions.
- Wider application including more complex landscapes such as several hillslopes within a sub-catchment.

This index is intended as an improved indicator of the potential leakiness of landscapes where suitably precise DEMs are available, rather than an attempt to calculate actual losses of water and sediment from catchments.

LEAKINESS & COARSER RESOLUTION DEM

Our final development of an up-scaled landscape leakiness index is conceptual at this stage. We see potential benefit in combining multitemporal satellite imagery with the GEODATA 9-second DEM (see http://www.ga.gov.au/nmd/products/digidat/dem_9s.htm). This could provide a rapid way of estimating temporal trends in relative leakiness per pixel for large areas. Multitemporal estimates of vegetation cover could come from MODIS imagery (250+ m pixels) or from finer resolution Landsat imagery where suitable databases exist (e.g. the Australian Greenhouse Office database (Richards and Furby, 2002) that provides continental coverage at 25 and 50 m pixel resolution). The coarse resolution DEM when combined with MODIS imagery may dictate that we look at the relative leakiness of pixels, and change in their leakiness values over time, rather than potential resource transfers amongst pixels. However appropriate statistical summaries may make it possible to compare the leakiness of similar landscape types (e.g. paddocks) with different grazing management histories. Stay tuned for further developments.

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